The influence of environmental policy on innovative behaviour an econometric study

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Summary

The political and scientific debate related to a sustainable development has stressed above all the importance of environmental innovations with respect to exploiting resources, to production, consumption and disposal. Such environmental innovations can:

- develop, introduce and apply new ideas, behaviour patterns, products and processes; and then,
- reduces the environmental burden or contribute to ecologically specified sustainable targets.

During the past 20 years, innovation has taken place primarily in end-of-pipe technologies, which has already resulted in considerable reductions in environmental pressure. However, the demanding criteria for sustainable development cannot be met by this alone. In future it will therefore be crucial to work towards additional technological change and a shift in the direction taken by progress up to now, through the development and application of new, sustainable manufacturing techniques and products. Policy planners and decision-makers are now faced with the central question of how an innovation-friendly regulatory regime of environmental policy approaches looks like.

The paper examines the determinants that influence the environmental innovation behaviour of companies in Germany in a multivariate context by using the environmental innovation behaviour of companies in Germany in a multivariate context by using data from the Mannheimer Innovationspanel 1993, which was part of the Community Innovation Survey. The objective is to analyse the general structures of the determinants of environmental innovation, as well as the specific impact of environmental policy instruments as an integral part of this framework. The pressure of environmental policy instruments on the innovation behaviour of companies is reproduced by indicators, which are investigated in a written survey at the level of the German Chambers of Commerce. Because of the complexity of the system of determinants and the difficulties in isolating the effects of environmental policy instruments, the study in hand is an explorative work in a methodological and empirical matter.

Keywords: Environmental innovation, environmental policy, determinants of innovation, firms, technological change.

1 Introduction*

By shaping the external framework conditions for companies, the state is an essential determinant of the extent and direction of company innovation. Since the start of the 1970s, environmental policy instruments have been implemented in many countries, thereby exerting a considerable influence on the behaviour of companies with respect to the environment.

With the increasing importance of environmental policy intervention in the economy, it is becoming ever more important to be able to determine the interaction between the application of environmental policy instruments and innovative behaviour. While it is generally recognised that it has been possible to decouple pollutant emission trends from economic growth through the influence of state environmental policy, its effects on innovative behaviour and the competitiveness of businesses is nonetheless a controversial topic in the debate on national competitiveness. One side argues that the burdens placed on business by environmental policy, where civil law instruments have been dominant up to now, limit the readiness to innovate and could therefore harm international competitiveness. The other side puts the case that environmental policy measures provide stimuli to innovate and drive technological change forward.

Questions relating to environmental policy and innovation fall between the disciplines of innovation research and environmental economics. Currently available environmental economic research on the innovation effects of environmental policy instruments is predominantly theoretical (cf. Jaffe/Palmer 1996:4). Innovation and technological progress are considered only superficially in the economic models. For example pollutant-specific framework conditions, such as the available preventive technologies or the existing emitter structure, both of which are necessary in realistic models are mainly excluded. Also generally no distinctions is made between different technology options, such as integrated or end-of-pipe technologies. Nor is there a great number of empirical studies on the relationship between environmental policy and innovation (cf. inter alia Green et al. 1994:1048).

This paper aims to study the operation and effects of environmental policy instruments on the environmentally innovative behaviour of companies in an empirical analysis, narrowing to some extent the research gap here.

2 The available data

Statistical investigation of the relationship between environmental policy and innovation is made more difficult by the inadequacy of available data. The lack of data prompted Hartje and

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Zimmermann (1988:16) to point out this gap in empirical environmental policy research more than a decade ago.

This study evaluates data collected in 1993 for the Mannheim Innovation Panel (MIP) from German companies.[1] In the 1993 wave, companies were asked about innovation goals which also included environmental targets. This included questions about the importance of environmental innovation in products and processes and of reducing consumption of energy and raw materials. Thus data is available for a cross-section of companies, making it possible to highlight differences between their attitudes to environmental innovation and to identify microeconomic categories of environmentally innovative behaviour.

Table 1: Share of branches in the sample
[unweighted and weighted data in % of the companies]

Branchen	**unweighted**	**weighted**
mining	4,9	1,2
food	4,7	9,3
textiles	4,9	8,2
wood	6,0	14,0
chemicals	14,3	12,2
ceramics	4,3	5,6
basic metal	3,6	2,6
metal working	10,0	15,5
machinery	21,5	10,9
office equipment	8,7	6,4
control eng.	7,1	5,9
transport	6,2	2,5
other	3,9	6,0
total	100	100

Source: MIP 1993

Table 2: Share of companies in the size classes
[unweighted and weighted data in % of the companies]

Size	**unweighted**	**weighted**
< 50	34,0	74,4
50 – 199	27,0	21,1
200 - 499	16,4	3,0
500 - 999	9,9	0,8
> 1000	12,7	0,7
Summe	100	100

Source: MIP 1993

The 1993 MIP innovation survey[2] was part of the Europe-wide Community Innovation Survey (CIS), initiated by the EU Commission and EUROSTAT and conducted in every member state. The MIP innovation surveys will, as of 1993, be conducted annually by the Centre for

1 For a description of the Mannheim Innovation Panels see Harhoff, D./ Licht, G. (1994: 255ff.).

2 See e.g. Felder et al. 1994.

European Economic Research (ZEW) for the Federal Ministry for Education, Science Research and Technology (BMBF).

In 1993, questionnaires were sent to a total of 13,317 companies, of which 2,954 participated in the survey.[3] For the present study, 2,481 companies were selected from the sample. The selection considered only companies in manufacturing industry, ignoring the service sector. Of the 2,481, 1,666 (67%) are located in western Germany, 815 (33%) in the "new
The NACE branch categories have been grouped into 13 economic branches for the purposes of this survey. Tables 1 and 2 show the distribution of the chosen companies among these super-branches and according to the five company sizes.[4]

3 The analytical model

The present study takes a relatively broad, microeconomic definition of innovation, including both innovation in the form of new products or processes and organisational innovation. While Schumpeters concept of innovation requires market novelty, and thereby views innovation at the level of national economies, this paper has chosen to use a company-specific perspective, which makes it easier to distinguish innovation, which can prove difficult in practice. In addition, the innovations at company level, which are especially important for the environment, can be adequately registered.

Environmental innovation is defined as innovation which serves to prevent or reduce anthropogenic burdens on the environment, clean up damage already caused or diagnose and monitor environmental problems.

In the debate on factors influencing innovation, innovation economists are now agreed that both supply and demand side factors have an effect. However, the special qualities of environmental innovation and the specific importance of environmental policy instruments as supply and demand side factors has until now been more or less ignored. Observing environmental innovation extends current models of innovation, as the public good component in environmental goods means that the returns on innovation are often uncertain and are garnered in the long-term and/or by third parties. The Supply and demand side impetus is therefore very much dependent on the use of environmental policy instruments.

The majority of available studies on the relationship between environmental policy and innovation have come from environmental economics. They take a somewhat mechanistic approach, based on traditional neo-classical environmental economic theory, where the innovation effects of environmental policy instruments are studied according to the criterion of

3 The response rate corresponds to the normal rate in written company surveys, around 25%.

4 The descriptive analyses refer principally to the MIP sample, which used a corrected selection procedure (cf. Harhoff/Licht et al. 1996:97ff.).

dynamic efficiency. As a result, economic instruments such as taxes or certificates are shown to have advantages in this respect. However, empirical studies have not always confirmed this to be the case (cf. Hemmelskamp 1997a).

The fundamental fault in an environmental economics approach is its failure to note the complexity of existing structures influencing environmental innovation. Looking at the influence of environmental policy from the perspective of innovation research, it becomes clear that the use of environmental policy instruments must be considered as a part of a system of interdependent structures influencing innovative behaviour.

For an analysis of instruments to be productive, a linkage is therefore necessary between the results of the debate on environmental policy instruments and the supply or demand side factors (for a detailed discussion of this approach see Hemmelskamp 1997b; cf. also Kemp 1996 and 1998 or Rennings 1998).

The use of environmental policy instruments represents an additional factor within a package of important framework conditions, through which the room for manoeuvre in environmentally oriented innovation decisions by companies is greatly restricted. It is important to distinguish between factors influencing the development and the application of environmental technologies, as users are not necessarily also the developers of such technologies, so that environmental innovation can also be observed in companies not directly affected by environmental policy measures. In the following it will be assumed, building on recent innovation research that the development of environmental technologies is influenced by:

- The use of environmental policy instruments
- Technological conditions, in the form of a company’s internal and external knowledge base
- The effectiveness of protection for the returns from innovation
- The structure of the environmental technology market and the size of companies
- Demand from the users of environmental technology

The following factors are assumed to influence the application of environmental technologies:

- The use of environmental policy instruments
- Access to information about environmental technologies
- The costs of environmental technologies
- The technological and economic risks in using environmental technologies

4 The hypotheses of the study

Within the above theoretical framework for this analysis, various hypotheses as to the possible influence of these factors on the generation of environmental innovation can be formulated. They will later be tested econometrically in Section 6.

The basic hypothesis of the study derives from the results of existing environmental economics studies (cf. e.g. Kemp 1996 or Hemmelskamp 1997a), the majority of which, as mentioned above, come to the conclusion that economic instruments have advantages over civil law instruments in terms of dynamic efficiency:

Hypothesis 1: Economic instruments provide a stronger stimulus for innovation than civil law instruments.

The remaining hypotheses were formulated on the basis of univariate analyses of the 1993 MIP data. In descriptive studies, indications have been found for certain factors, which could affect the importance of environmental innovation for a company.

For example, the MIP data on company employment levels relate to the structure of company size among environmentally innovative companies. It emerges that environmentally oriented innovation goals have a higher status in larger companies than in smaller or medium-sized ones.

Hypothesis 2: The larger the company, the more environmentally innovative it is.

It has been shown that R&D have a lower status in environmentally innovative companies than in others.

Hypothesis 3: Environmentally innovative companies have low R&D intensity.

It could be observed that environmentally innovative companies assigned greater importance to cooperation on R&D.

Hypothesis 4: Environmentally innovative companies are heavily involved in cooperative R&D projects.

The development of demand between 1993 and 1995 is viewed more positively by environmentally innovative companies.

Hypothesis 5: Environmental innovation is strongly dependent on positive expectations about demand.

Securing returns on innovation through the use of protection instruments is more important to environmentally innovative companies than to environmentally non-innovative ones.

Hypothesis 6: Protecting returns on innovation is especially important In environmental innovation.

The information requirement of environmentally innovative companies is higher. It can be seen that the marketing and sales departments in particular are important internal sources of information and customers an important external source for environmentally innovative companies.

Hypothesis 7: Environmental innovation demands that companies possess a great amount of internal and external information.

It has emerged that environmentally innovative companies are obstructed to a greater extent by state influence than less innovative ones. This discrepancy in the assessment of state influence could reflect the effects of environmental policy measures.

Hypothesis 8: The greater the obstruction by lengthy administrative procedures, the greater the importance of environmental innovation.

5 Constructing a regulatory indicator

Information on the pressure to act brought to bear on companies by environmental policy instruments is not available. As a consequence, it is hard to measure the influence of environmental policy directly (cf. Cottica 1994:36). Many studies therefore create indicators which depict the influence of instruments.

The sole observable indicator is the rate of environmental investment. In a panel study, for example, Jaffe/Palmer (1996) use the rate of investment expenditure and running costs for the branch as an indicator of the pressure exerted on companies by environmental regulations. Assuming that the rate of environmental investment is dependent on the implementation of environmental policy measures, the present study could use the ratio of environmental to total investment as an indicator of regulatory intensity. However, although Lanjouw/Mody (1996:554) consider such an indicator to be meaningful, its appropriateness for this study is only limited. Several points can be made against its use here.

In the first place, the Federal Statistical Office's data on company environmental investment considers principally end-of-pipe technologies, as investment in integrated technologies is hard to identify statistically. An indicator based on these data would therefore show too low a regulatory intensity in precisely those branches where environmental successes have been achieved to a great extent with integrated technologies. Secondly, the indicator is unsuitable because the present study defines innovation at the level of the company, and the transition from innovation to investment is therefore inconstant. The rate of environmental investment should therefore be considered as an endogenous variable in the models, and not as exogenous. Thirdly, the rate of environmental investment only makes possible conclusions about environmental innovation by users and not suppliers of environmental technology. Fourthly, this indicator allows no distinction between the various types of environmental policy instrument.

Another measure of regulatory intensity is the size and number of environmental laws and regulations passed. This indicator is, however, also unsuitable for the present study, as conclusions can only be drawn from analyses over a number of years. A sector-specific study cannot be carried out, and one can scarcely assume that there is a correlation between the length of legal texts and the pressure for action which they exert. Finally, this indicator also fails to permit differentiation between different environmental policy instruments.

The instrument-specific indicator required by this study can be gained from a survey. As it was not possible to carry out an additional company survey, a limited written survey of the German chambers of commerce (IHKs) was conducted for the purposes of this study. The environment officers at the IHKs were asked to estimate the extent to which companies were affected by environmental policy instruments at branch level, something which the IHKs, with their intersectoral functions and information, are in a good position to estimate. In contrast, industrial associations, such as for the chemicals industry (VDC) or engineering (VDMA), are less suitable because of their sector-specific perspectives.

Figure 1: Impact on German industries caused by environmental policy [median] (see end)

The disadvantage of this branch indicator is that the variation in regulatory intensity within the branch cannot be determined. For example, operators of old plant are more heavily affected by environmental regulations on exhaust gases than those operating new plant. The assessments reached by the IHKs must also be seen in the context of the different economic structure of their respective regions, which strongly determined their judgement.

The IHKs were asked in three questions to estimate the extent to which the 13 branches defined for the study were affected by environmental policy in general and environmental taxes or standards in particular. Answers were given on a 9-point scale from “not affected” to “heavily affected”. Eighty questionnaires were sent to the IHKs, 19 of which responded. Eighteen responses could be evaluated, corresponding to a more or less standard response rate of 22% for written surveys. The results of the survey are summarised in Figure 1 which shows the median assessment for each branch. There are clear differences between the assessments for different branches.

In interpreting these results, it should nevertheless be noted that environmental taxes are used only in isolated cases in Germany. As Oates et al. (1994:22) point out: “Finding the appropriate data (...) to test for differential effects of command and control versus incentive-based environmental regulation could be difficult given the dearth experience with regulations other than command and control”. It can therefore be assumed that that judgements on the extent of the impact of taxes are characterised less by experiences with this instrument, and rather more by the heated debate on the introduction of eco-taxes..

6 Econometric analysis of the factors influencing environmental innovation

6.1 Company innovation goals as exogenous variables

In the MIP, companies were asked to make a subjective estimate of the importance of 21 innovation goals on a scale of 1 to 5 (no importance to very high importance). Possible goals offered in the questionnaire included creating new markets, extending the product range or reducing environmental stress. These goals can be used in multivariate analysis as endogenous variables, to explain which factors determine the importance of environmentally significant innovation goals to companies. One possibility for distilling the relevant environmental innovation goals from the given innovation goals is a factor analysis. Here structures can be drawn out between the individual innovation goals, thereby giving an indication as to which innovation goals can be assigned to a particular innovation strategy.

Using factor analysis, five factors were drawn from the mass of variables made up by the innovation goals. These can be interpreted as business strategies for reducing costs, expanding global markets, expanding local markets, environmental protection and securing markets. An overview of the results of the factor analysis is given in Table 3. The strongest relationships between individual goals and the five strategies are shaded for emphasis. The higher the factor value, the stronger the connection between the importance of the innovation goal as stated in the survey and a business strategy. Some innovation goals are closely related, not only to one, but also to several business strategies. An interpretation must take account of the relationships between these goals and the corresponding strategies..

Table 3: Factor analysis: Structure of the innovation objectives

	reducing costs	*expanding global markets*	*expanding local markets*	*environmental protection*	*securing markets*
Replace old products	0,091	0,273	0,132	-0,013	0,404
Defend or enlarge market share	0,123	0,100	0,209	0,043	0,406
Expand main activities	0,087	0,092	0,213	0,055	0,360
Expand other activities	0,085	0,094	0,112	0,050	0,216
New markets in the Old Laender	0,106	0,099	0,626	0,045	0,092
New markets in the New Laender	0,114	-0,005	0,633	0,123	0,046
New markets in Eastern Europe	0,049	0,343	0,447	0,066	0,053
New markets within the European Union	0,095	0,519	0,467	-0,003	0,091
New markets in Japan	0,012	0,737	-0,004	0,079	0,041
New markets in the United States	0,031	0,822	-0,013	-0,006	0,039
New markets in other countries	0,046	0,688	0,187	0,017	-0,007
Improve product quality	0,286	0,034	0,131	0,293	0,301
Develop environmentally-friendly products	0,074	0,124	0,134	0,518	0,194
Increase flexibility of production process	0,405	0,006	0,162	0,277	0,246
Reduce wages	0,592	0,039	0,054	-0,010	0,072
Cut down on raw material used	0,628	0,076	0,085	0,125	0,025
Cut down on energy used	0,554	-0,033	0,087	0,427	-0,104
Reduce set-up time of production	0,643	0,080	0,093	0,208	0,073
Reduce rejects in production process	0,557	0,068	0,045	0,314	0,124
Improve working conditions	0,385	-0,004	0,091	0,563	0,031
Reduce environmental impact	0,241	0,037	0,010	0,679	-0,025

Note: unweighted data; Cronbachs α =0,818
Source: MIP 1993

Even if the factor values are sometimes relatively low, 0.2 – 0.3, an interpretable factor structure can nonetheless still be made out. It is unsurprising that developing environmentally friendly products and reducing energy consumption or pollution belong to the environmental protection strategy. The environmental aspect in reducing environmental stress during production and developing environmentally friendly products is obvious. The contribution from reducing energy consumption is also understandable, with the possible reductions in emissions from energy production. Alongside these three goals, improving product quality and improving working conditions can also be assigned to environmental protection, although improving product quality has relatively low factor values both for environmental protection and for reducing costs and securing markets, and so this goal is not used in interpreting the environmental protection strategy.

The high factor value for improving working conditions can be explained by the close relationship between safety at work and environmental protection. Environmentally harmful production processes, for example pollutant emissions in automobile paint shops, can affect the health of those working there, or accidents at the workplace, such as when working with poisonous substances, can lead to considerable environmental pollution. On the other hand, it is surprising that environmental protection receives such a low value from reducing materials consumption, even though reducing the consumption of resources is an essential component in measures to realise sustainable development (cf. Pearce/Turner 1990:43). Reducing materials consumption has a high factor value only with the reducing costs strategy, form which it can be concluded that reducing materials intensity is seen by companies primarily in terms of efficiency, as a measure for saving costs.

As well as identifying the goals of environmental innovation, the factor analysis also allows further conclusions as to company innovation activities. Innovation goals with a high factor value for several innovation strategies imply complementary goals, i.e. that other intentions are simultaneously associated with an innovation goal. Cottica (1994:32) shows that environmental innovation in the Italian packaging industry cannot be separated from innovation to reduce costs. For German manufacturing industry, such a link between efficiency and environmental protection can only be found for reduction of energy consumption.

This innovation goal has high values both for environmental protection and for reducing costs. The higher factor value for reducing costs nevertheless implies its somewhat greater significance as motivation for reducing energy consumption than that of environmental protection.

In the following analyses, the four innovation goals of reducing environmental stress during production, developing environmentally friendly products, reducing energy consumption and improving working conditions are defined as environmental innovation goals. However, because of its importance to the idea of sustainable development, the innovation goal of reducing materials consumption is also included in the analyses..

6.2 The basic model

Five multivariate models in all are tested, and the aforementioned environmental innovation goals serve as endogenous variables. The dependent variables are given an ordinal value on a scale of 1 (no importance) to 5 (very great importance).

On the basis of these categories of dependent variable – and assuming a normal distribution – ordered test models are designed. Using the 1993 MIP data, it is unfortunately not possible to distinguish between users and developers of environmental technology.

The factors which were observed to affect the importance of environmental innovation goals in the descriptive analyses are accounted for as exogenous variables in the models (cf. Table 5).

Table 5: Overview of the exogenous variables in the models

Variable	*Values*
Market structure and growth	
Development of demand in the next three years	ordinal (-2 - +2)
Company size in employees (log)	Number of employees, logarithm
Company size in employees (log^2)	Number of employees, logarithm, squared
Technological opportunities	
R&D intensity	R&D expenditure / turnover
R&D cooperation	(0/1)
Technical possibilities exhausted	ordinal (1 - 5)
Lack of information on external knowledge	ordinal (1 - 5)
Protection mechanisms	
Patents	ordinal (1 - 5)
Copyright	ordinal (1 - 5)
Secrecy	ordinal (1 - 5)
First mover	ordinal (1 - 5)
Complexity of product	ordinal (1 - 5)
Long-term employee relations with qualified personnel	ordinal (1 - 5)
Sources of information	
Internal	ordinal (1 - 5)
Suppliers of primary products, materials, components	ordinal (1 - 5)
Suppliers of equipment	ordinal (1 - 5)
Customers	ordinal (1 - 5)
Immediate competitors	ordinal (1 - 5)
Consultants, market researchers	ordinal (1 - 5)
Industry-financed research institutes	ordinal (1 - 5)
Universities and technical colleges	ordinal (1 - 5)
Large research institutes	ordinal (1 - 5)
State influence, costs, risks	
Innovation risk too high	ordinal (1 - 5)
Lack of capital	ordinal (1 - 5)
Administrative procedures too long	ordinal (1 - 5)
Region	
“Old” / “New” Länder	(0/1)
Environmental policy	
Environmental regulation	ordinal (1 - 9)
Environmental taxes	ordinal (1 - 9)

The majority of the exogenous variables are given an ordinal value. Alongside the two variables for regulatory intensity, this also applies to the importance of the length of administrative procedures, innovation risk and the availability of outside capital as obstructions to innovation, for example. The hypothesis that environmentally innovative companies show a comparatively low R&D intensity is tested in the model by considering the share of R&D expenditure in total turnover for 1992. The influence of protection mechanisms is registered in variables for the importance of a first mover or copyright, for example. The importance of various source of information is measured through variables for the importance of internal and external information exchange.

The significance of R&D cooperation and the company's location are measured as binary variables. Company size is given in terms of employees, using both the logarithm of the employees (in full-time equivalencies) and the log squared, in order to discover any non-linear connections between levels of employment and the importance of environmentally oriented product innovation. On a logarithmic scale, the differences in company size are no longer weighted linearly. If the coefficient in the model is positive, the factor has a positive effect on the importance of an innovation goal. The estimated results from the five models are given in Appendix 1.

6.3 Model 1: Developing environmentally friendly products

A company's development of environmentally friendly intermediary and final products can address a variety of aspects. Increasing the useful life and reparability of products could, for example, be a goal, or replacing environmentally harmful chemical components, making products reusable, improving disposability, minimising atmospheric emissions or noise during the use of the product or reducing the costs incurred through environmental taxes. Environmentally oriented product innovation can also serve to improve a company's competitiveness. When, for example, an engineering firm develops and introduces an emissions filter, this is an innovation aimed at gaining market share in environmental technologies.

Primarily for intermediary – but also for final – products, regulatory, prohibitive and monitoring instruments play a key role in product-related environmental policy. Starting from the companies' familiarity with these instruments, one might expect a positive coefficient for standards. However, the model shows a significant negative relationship between the extent to which companies are affected by environmental standards and the importance of environmentally oriented product innovation (cf. App. 1).

The introduction of new product-based environmental standards would therefore increase the likelihood of negative innovation stimuli for environmentally friendly products. The burden placed on companies by environmental standards for products has presumably reached a critical level and the overregulation with respect to the environment which is often expressed by company representatives is making itself felt. The use of economic instruments, which can only be seen in isolated cases as part of an instrument mix for end products, could have a positive effect on innovation. A significant positive relationship is evident between environmental taxes and the importance of innovation to develop environmentally friendly products. Financial incentives, such as introducing taxes on certain products or packaging, or the payment of compulsory deposits, would therefore cause a company to take more account of environmental criteria in its product development innovation.

The length of administrative procedures also has a positive relationship to innovation efforts in this respect. Thus companies who feel themselves held back in their innovative activities by lengthy administrative procedures will push forward the development of environmentally friendly products. The effects of environmental legislation are nonetheless offset by the variables for environmental taxes and standards. It can therefore be presumed that this effect reflects the structure of public administration and the influence of bans, permissions and registration procedures, regulations for use or obligatory informational instruments decreed for health and safety reasons. Developing environmentally friendly products can also meet the requirements of these regulations if, for example, the use of environmentally friendly paint in automobile manufacture also reduces the exposure of employees in the paint shop.

In contrast, no influence from environmentally oriented demand can be made out. Surprisingly, neither past nor expected market demand up to 1996 has particular importance for the status of environmentally friendly product innovation. It might have been supposed that, contrary to this result, market forces – i.e. demand for environmental technologies – from companies facing regulation or environmentally aware consumers would provide a decisive stimulus for generating environmentally oriented product innovation. In the paper industry, for example, it has been shown that demand from end users had a strong influence of the development and launch of recycled paper products (cf. OECD 1991:30; Wong et al. 1995:6). However, this result could be due to qualitative changes in market demand, without any quantitative effects. This hypothesis is strengthened by the influence of consultants and market research companies as an information source for environmentally oriented product innovation, indicating the importance of market trends.

A U-shaped relationship emerges between the number of employees and the importance of innovation to develop environmentally friendly products. Up to staffing levels of around 190, the importance of this innovation goal falls as company size increases. This effect is then reversed and the importance of the environmental goal starts to rise again. However, the effect is not linear, so that the importance enjoyed in very small companies is not reached again until employment rises to 33,000. Thus environmentally friendly product innovation has a high status above all in small and very large companies. Any distortion due to differing R&D intensities can be excluded by including it as a variable.[5] Here the structure of small and medium-sized companies among suppliers of environmentally friendly products makes itself felt. Adler et al. (1994:115f.), for example, showed in a written survey that over 58% of companies in the environmental technology industry had under 100 employees (see also Halstrick-Schwenk et al. 1994:113ff.). Environmentally friendly products appear to represent an attractive niche market above all for small, innovative companies. Its importance for very large

5 When interpreting the results it should be remembered that no distinction can be made between developing environmentally friendly consumer products and environmental technology.

companies, on the other hand, could be for reasons of image, as the development and launch of environmentally friendly products enables well-known companies to present themselves in a positive light to what is a critical public.

The great importance of a first mover behaviour as a mechanism for protecting innovation returns implies the significance of setting the pace. The high positive relationship leads one to conclude that knowledge advantages in developing environmentally friendly products can be exploited above all by rapidly going to market.

However, because of the significant negative relationship between innovation risk and the importance of the innovation goal, it can be assumed that innovation is heavily concentrated on low-risk incremental change in parts or components of products already on the market, and therefore builds predominantly on existing technological discoveries.

The assumption that incremental innovation is especially important is supported by the companies' low R&D intensity. The significant negative correlation between R&D intensity and the importance of this innovation goal in the model indicates that there is greater likelihood of environmentally oriented product innovation in companies with low R&D intensity. Correspondingly, cooperative R&D also proved insignificant for the development of environmentally friendly products. This matches results from Halstrick-Schwenk et al. (1994:132), who show that a large number of companies in the environmental technology industry do not conduct their own R&D.

The necessary scientific expertise is gained through information transfer from universities and technical colleges in place of R&D. The model shows a significant positive correlation between importance of further education establishments as a source of information and the innovation goal. But information transfer has in any case an important function in the development of environmentally friendly products. This includes both external information from suppliers of primary products or materials and internal sources, for example the marketing department. This result is plausible, as the environmental soundness of a product is determined not only directly by the innovator but also by the primary products and materials used.

Finally, it should be pointed out that there is no evidence for a difference between the “old” Länder as to the importance of innovation in developing environmentally friendly products.

6.4 Model 2: Innovation to reduce environmental impact of production

Environmentally oriented process innovation serves to prevent or reduce emissions or to reduce the costs incurred through environmental taxes. This can be achieved with various forms of integrated and additive environmental innovation by companies, for example by capturing emissions and residues to avoid polluting the air, water or soil, using filters and sewage treatment plants, settlement tanks or accident precautions. This also includes environmentally optimising the production process with technical or organisational means, such as improving energy and materials efficiency, substituting environmentally harmful process materials or closed systems for reusing water and materials.

The influence of environmental policy instruments on the importance of this innovation goal varies. There is no significant relationship between the degree to which companies are affected by environmental standards and its importance. The likelihood that the importance of environmentally oriented process innovation will increase is thus unaffected by the introduction or tightening up of environmental standards. Within the current frameworks conditions, they do not therefore appear to be a suitable instrument for inducing greater environmental orientation in process innovation. On the other hand, positive effects on innovation can be induced by the use of economic instruments (cf. App. 1). There is a significant (up to a level of 10%) positive correlation between the variable for environmental taxes and the innovation goal. From this it can be concluded that the likelihood of innovation to reduce production-related environmental stress will rise with the introduction of environmental taxes.

The significance of this innovation goal also rises due to a company’s being heavily burdened with lengthy administrative procedures. A significant positive relationship can be observed between the importance of over-long administrative procedures as an obstacle to innovation and the importance of the innovation goal. Since the influence of environmental policy action is already accounted for in the regulatory indicators, the correlation might indicate the importance of the time-lapse between planning and realising process innovation, which can be drawn out by public protest or objections on the grounds of environmental risk. In this case it can be assumed that public resistance which lengthens procedures increases the willingness of companies to defuse existing environmental disputes with the public or representatives of environmental interests by developing and introducing environmentally sound production processes, thereby speeding up the realisation of investment processes.

Just as with developing environmentally friendly products, R&D has little value in respect of innovation to reduce production-related environmental stress. This innovation goal is pursued above all by companies with only a low R&D intensity.

There is a significant positive relationship between the innovation goal and the importance of equipment suppliers as a source of information. As the importance of information from equipment suppliers rises, so does the likelihood of innovation to reduce production-related environmental stress. Another important source of information for the companies are the universities and technical colleges. The model thus indicates a high status for external technology transfer in developing environmentally sound production processes, both in the low R&D intensity of innovators and in the importance of equipment suppliers as a source of information.

Security for the returns on innovation to reduce production-related environmental stress is given mainly by the structure of the production process. Companies appear to make it more difficult for potential imitators to re-engineer their production processes through complex structures in their own.

Company size has a strong influence on environmental process innovation. A non-linear correlation can be seen between the number of employees and the importance of the innovation goal. Up to around 171 employees, the importance of the innovation goal falls as employment levels rise. However, its importance then rises as the number of employees increases. The accumulated upward trend nonetheless fails to reach the levels found with very low employment until the number of employees rises to about 28,500. Thus it is first and foremost the very small and very large who aim to reduce production-related environmental stress, while these activities are least important to medium-sized companies.

6.5 Model 3: Innovation to reduce consumption of materials

The data on the goal of "reducing production costs by cutting the consumption of materials" make possible a more detailed analysis of environmentally oriented process innovation. Reducing materials consumption during the production process by using resource-efficient technologies is of great importance in realising sustainable development. Savings in materials can be achieved by converting raw materials more efficiently or implementing closed systems to reuse water and other substances.

The above factor analysis showed that companies pursue innovation to reduce materials consumption only in order to reduce costs, while the environment is irrelevant in this respect. The suspicion that this characteristic is due to inadequate incentives for innovation in current output-oriented environmental policy is confirmed by econometric analysis (cf. App. 1).

No significant correlation can be found between pressure to act brought to bear by environmental taxes or standards and a reduction in materials consumption. The likelihood of more innovation to reduce consumption by companies does not rise with the introduction or tightening up of existing standards. Nor can a greater importance be expected for innovative efforts to save materials from the introduction of environmental taxes. This is surprising, in view of the financial incentives provided by taxes, which would lead one to assume that cost reduction and environmental goals would complement one another. Thus the result should be interpreted above all in the light of the scant experience companies have had with environmental taxes.

Innovation to reduce materials consumption is not associated with intensive R&D. On the contrary, the less important R&D is to a company, the higher the status of innovation which saves on materials. This is not surprising, as the materials-intensive companies in the basic materials and production goods industries in particular tend to have a relatively low R&D intensity. Companies making efforts to increase materials efficiency are therefore predominantly technology users. This also applies to companies in the “new” Länder who, within the given framework conditions, assign recognisably more importance to innovation which reduces materials consumption than companies in the “old” Länder. Here the great need for modernisation in the “new” Länder appears to be making itself felt, where inefficient use of materials in particular represents a serious obstacle to competitiveness.

Logically enough, suppliers of primary products, materials and components also have an important function as a source of information on innovation to save materials, as the significant positive correlation with the goal of “reducing materials use” implies. But immediate competitors are also an important source from which to gather information on implementing such innovation.

Long-term working relationships with their staff are viewed by companies as the most effective way of protecting the returns on their innovation. It appears therefore that specific expert knowledge of production processes is important for this form of innovation. In contrast to reducing production-related environmental stress in general, innovation to reduce materials consumption is not affected by company size. Regardless of the size of the company, reducing consumption of materials is an exercise in cost reduction.

6.6 Model 4: Innovation to reduce energy consumption

Besides the data in the previous section, analysis of innovation to reduce energy consumption reveals further specific details of the factors influencing environmental process innovation. Reductions in energy consumption can be achieved through organisational innovation, such as altering the behaviour of users or restructuring the company structure. Technological innovation is also possible, for example completely upgrading production plant, substituting fuels or action to use energy more efficiently.

Innovation to save energy can as easily be stimulated by environmental policy measures as hindered. The effect on innovation is determined by the choice of policy instrument. Introducing environmental taxes appears to be associated with a negative effect on energy-saving innovation, while positive stimulation of innovation can be expected from new or more stringent environmental standards.

A significant positive correlation at 1% exists between environmental standards and the innovation goal, while the correlation between taxes and the goal is significant and negative at 10%. The result is surprising in the context of the debate in environmental economics. Environmental taxes are held to be more efficient than regulation, partly because of their more powerful effect on innovation. The result from the model should therefore be interpreted in the light of the heated debate over introducing energy taxes which took place in the early 1990s. The dominant view in German companies was that the introduction of energy taxes would bring about a considerable worsening of their international competitiveness, especially in the energy-intensive sectors (cf. Voss 1995). Because of the great uncertainty about the operation and effects of these taxes, it can be assumed that standards are preferred by companies as, after many years of experience with them, they can better estimate the effects of these familiar instruments.

Industrial production in the “new” Länder at the start of the 1990s was notable for inefficient use of energy. As a result, innovation to reduce energy consumption is also more important to companies there than in the “old” Länder. There is a significant positive correlation between location in the “new” Länder and the importance of this innovation goal (cf. App. 1).

Companies with low R&D intensity ascribe greater importance to energy-saving innovation in the production process that those who conduct extensive R&D. This is indicated by the significant negative relationship between R&D intensity and the innovation goal. As might be expected, exploiting the existing technological structure in private-sector research institutes and universities or technical colleges is an important source of information for innovation to save energy in the production process. The significant positive correlation between the innovation goal and the importance of equipment suppliers as information sources implies that the necessary energy-saving technology is obtained from the investment goods industry. The significant positive correlation between the importance of internal information sources and of the innovation goal underlines the necessity of linking together the various functions within a company. Energy-saving innovation appears to require detailed knowledge of production processes, which can be used through communication between different company departments, such as development, production, logistics and management, to exploit fully the existing potential for saving energy.

Company size shows a non-linear relationship to energy-saving innovation. At first, there is a negative correlation to the innovation goal, i.e. as the company becomes larger, the importance of reducing energy consumption falls. The curve has its minimum at 136 employees. After that, a positive relationship can be seen, although the company size must reach 18,000 employees before energy-saving innovation regains the importance it had for very small companies.

In securing returns on energy-saving innovation, gaining a headstart on the competition is important. Rapid implementation of process innovation to save energy thus appears to be important in achieving and securing a lead over competitors in terms of costs. Other protection mechanisms, such as patents or secrecy, have no particular value and/or are not viewed as effective appropriation instruments.

6.7 Model 5: Innovation to improve working conditions

The factor analysis carried out above showed that improving working conditions is viewed by companies as an element of their environmental strategy. However, while influence from environmental policy on the status of the other innovation goals in the environmental strategy could be clearly seen, there is no such correlation with improving working conditions. Neither environmental taxes nor environmental regulation correlate significantly with the importance of this goal. The positive relationship with lengthy administrative procedures does nevertheless indicate some influence from the state on its importance. It can be assumed that this effect is brought about by regulations on workplace conditions, for example. Although environmental policy measures thus have no influence, the inclusion of working conditions as part of the company environmental strategy can be explained by the way environment and conditions at the workplace complement one another closely (cf. App. 1).

The results from the model also show that improving working conditions has particular importance for very small companies. There is a non-linear correlation between the innovation goal and the number of employees. Up to around 550 employees, a negative correlation can be found, and as the number of employees increase further, the relationship is positive. The positive section of the curve is very shallow, however, so that the cumulated effect in small companies would not be achieved again until a company employed over 300,000. Notwithstanding, the result does not appear to indicate lack of interest in improving working conditions among medium-sized and large companies, but rather to the ground smaller companies need to make up.

Because of obsolete conditions in production in the “new” Länder, there was great need to improve working conditions there, above all at the start of the 1990s. This is shown in the model with a significant positive correlation at 10% between a company’s location and the innovation goal.

Here also, there is little importance ascribed to R&D. There is a significant negative correlation between both R&D intensity and R&D cooperation and the innovation goal. The lower the R&D intensity and the less important R&D cooperation, the greater the importance of the goal. To compensate of the lack of internal R&D capacity, companies use external sources of information. These include principally the universities and technical colleges, as well as the experience of consultants and private-sector research institutes.

Finally, it can be seen that the classic instruments for securing returns on innovation, patents or secrecy, are irrelevant for health and safety at work. This is plausible if one assumes that these measures are not associated with any cost advantages for the company over its competitors.

7 Summary of the results from the econometric models

The models confirm that environmentally oriented innovation is determined by a complex interaction between various factors. However, the hypotheses formulated about the factors influencing environmentally innovative behaviour are only partially confirmed by the multivariate analysis.

In the descriptive analysis, lengthy administrative procedures were seen to obstruct environmentally innovative companies more than others. It was therefore assumed that the importance of environmental innovation would increase as the companies faced more obstacles from drawn-out administrative procedures. One explanation for such a relationship between administrative procedures and environmental innovation might be the considerable red tap brought by environmental policy measures, for example when licensing new production plant (c.f. e.g. Rothwell 1992:455; Steinberg et al. 1991:37). If this association proved to be the case, the administrative burden placed on companies could be used as a proxy variable for regulatory intensity. However, the econometric models show that the significant influence of administrative procedures on environmental innovation goals remains even when regulatory indicators are taken into account. Only between administrative obstruction of the companies and the importance of materials-efficient process innovation – regardless of whether the model takes into account regulatory indicators – is there no connection. This means that the variable for administrative burden also reflects the effects of other state actions, such as health regulations for example, and is therefore unsuitable as an indicator of the intensity of environmental regulation.

The regulatory indicators used in the models are more meaningful variables for estimating the correlation between environmental policy instruments and the innovative behaviour of companies. Above all, they permit a comparative evaluation of the influence of an instrument to be made in the models, and thereby enable the hypothesis that a stronger incentive to innovate is produced by taxes than by standards to be tested.

It becomes clear that nothing can be said about the general advantages of one type of instrument over another. Innovation to reduce product-related environmental stress or to develop environmentally friendly products, for example, can be stimulated through the use of environmental taxes. Here the coefficients for taxes are different in the two models which, with some statistical reservation, suggests that environmental taxes have a stringer impact on the development of environmentally friendly products. This contradicts the arguments of Norberg-Bohm and Rossi (1997:2) concerning the US paper industry, according to which environmental standards promote less the development and rather more the diffusion of environmental technologies. On the contrary, the introduction or tightening up of standards to restrict the development of environmentally friendly products and has no impact on the importance of innovation to reduce environmental stress during production processes. One advantage of standards over taxes can, on the other hand, be found in their stimulation of innovation to reduce energy consumption, although this result must be interpreted with some care. Environmental policy has no effect on the importance of innovation to reduce consumption of materials or improve conditions at the company workplace.

Thus the results clearly show that a one-sided preference for economic instruments for economic goals is not sensible. The hypothesis that economic instruments should be preferred over civil law instruments must be rejected. The results prove instead the importance for innovation of a case-by-case choice of instruments, taking account of the respective framework conditions for innovation. The necessity of such a policy approach can also be seen in the example of water conservation described by Jänicke (1997). Under the influence of a variety of factors, taxes proved an effective instrument in the Netherlands, which success was achieved in Sweden through the use of subsidies.

The factors with a potential to influence environmental innovation include the size of the company. Opinion in the innovation literature is divided as to the impact of large or small companies on the development of new technologies (cf. e.g. Kleinknecht 1989). In the descriptive analyses it was observed that the status of environmental innovation goals was higher in larger companies than in smaller ones. This leads to the hypothesis, greater company size means a rise in the importance of environmentally oriented innovation goals, one which is reinforced by results from the research of Georg et al. (1992:538), which points to the restrictive effects on innovation from insufficient experience operating integrated technology in small and medium-sized companies. Rothwell (1992:455) also emphasises the disadvantages of smaller companies and points to the heavier burden from environmental policy measures which they bear, in comparison to larger ones. However, this research hypothesis is borne out only to a limited extent by the econometric analyses. While company size has no noticeable effect on innovation to save materials, the other models show a non-linear correlation between company size and the importance of innovation goals. Thus environmental innovation enjoys a high status above all in very small or very large companies, and is least important in medium-sized ones. For small companies, this result indicates, among other things, advantages in flexibility through less complex production processes and a greater willingness to exploit niche markets. The importance to very large companies can be explained both by their stronger public presence and by the stricter monitoring carried out by state environmental bodies (cf. e.g. Brännlund et al.1995:33).

The hypothesis that the importance of environmental innovation goals falls as R&D intensity rises is confirmed for all environmental innovation in the models. The result contradicts Jaffe and Palmer (1996:17), who noted a significant positive correlation between the level of environmental investment and R&D expenditure in a regulated sector. To interpret this result, as distinction must be drawn between product innovation and process innovation. In the case of environmental process innovation, the environmental technology industry is presumably very important as a technology supplier, and process innovators therefore require no intensive R&D. But environmental product innovators, who also include suppliers of environmental technology, ascribe little importance to R&D. One explanation may be the current dominance of end-of-pipe technologies, which are essentially merely incremental improvements to existing technological solutions, so that R&D is only required to a limited extent.

It could be seen from the descriptive investigation that the information requirement was greater for environmentally innovative companies. Information from internal sources and customers in particular was implied to be especially important to environmental innovators. From studying the models, however, it emerged that internal sources of information affect only energy-saving process innovation. While Georg et al. (1992:542f.), for example, ascribe great importance to the customer as a source of information for environmental product innovation, the models reveal no influence on the importance of environmental innovation. Instead, other sources proved to be significant, revealing in particular a high requirement for external information. For example, suppliers of equipment have an important function in providing information for innovation to reduce production-related environmental stress. This matches results from Georg et al. (1992:542f.), which also demonstrate the importance of suppliers for process innovation. The result reinforces the idea that process innovators obtain their environmental technologies predominantly from specialised technology suppliers. Suppliers of primary products, materials and components provide important information for developing environmentally friendly products and reducing consumption of materials. This appears sensible in both cases, as the environmental soundness of a product is heavily dependent on the materials used, and reducing materials consumption depends upon, among other things, information about possibilities for substitution.

However, it can also be assumed that the heavy information requirement is to a certain extent due to low R&D intensity in environmentally innovative companies. The strong influence of the public research infrastructure implies a need for additional outside expertise. The availability of information from universities and technical colleges exerts strong influence on the development of environmentally friendly products and improving company working conditions.

Concerning the influence of demand on the importance attached to environmental innovation, the hypothesis was formulated that environmentally innovative companies see demand trends more positively than others. However, this hypothesis must be rejected, as no impact on the part of demand development could be found for environmental goals.

Furthermore, the econometric analyses also make clear that appropriating returns on individual examples of environmental innovation takes place with a variety of instruments. Although an increase in the number of environmental patent applications has been observed in Germany in recent years, the models show that patent protection, as a classic means of legal protection for creating temporary barriers to market entry, has no influence on the perceived value of environmental innovation. This could indicate that environmental process and product innovation is less easy to patent, and that environmental innovation is therefore predominantly incremental in nature. In its place, a first mover behaviour is seen as valuable in protecting environmental product innovation. Companies can exploit this advantage to bind customers to a product and benefit from learning effects. On the other hand, a complicated process which competitors find hard to imitate influences innovation to reduce environmental stress caused by production. However, further differences emerge between specific innovations in production processes. For example, maintaining long-term working relationships with qualified personnel is significant in the case of process innovation to save materials and achieving to be a first mover with energy-saving process innovation. The classic protection mechanisms, such as secrecy, or stealing a march on the competition have no impact on innovation to improve working conditions. For this form of innovation there appears to be no competitive reason for protecting efforts in innovation.

8 Conclusion

This paper has examined the influence of environmental policy instruments on innovative behaviour by companies using quantitative and qualitative analysis in the context of interdependent structures of influence. Because of the complexity of the factors and the difficulty in isolating the effects of environmental policy instruments, the study is explorative in terms of methodology and as an empirical investigation. The key result is the recognition that the use of environmental policy instruments may have a far smaller impact on environmental innovation than has been assumed in the environmental economics debate, as other factors exert an equally powerful influence on innovative behaviour and thereby on the effects of the instruments. Environmental policy cannot therefore in itself promote environmental innovation, but policy measures must be implemented to take account of the respective technical and economic framework conditions in the situation to be regulated and of changes over time.

Further studies need to develop this approach further with a combination of environmental economics and innovation economics approaches. In particular, use should be made of policy evaluation approaches, as it is not only the use of an instrument, but also the political process of formulating demands which is important for the effectiveness of an environmental policy instrument. The effects of various instruments could be studied in more detail in microeconomic examinations, whereby the effects of instruments on different technology alternatives should be estimated. Here it is important to develop meaningful indicators for the effects of instruments and possibilities for depicting the characteristics of different technologies. The specific qualities of individual phases in the innovation process, i.e. the development and application of environmental technologies, should receive more attention, because when environmental goods fail in the market, there is not only a lack of motivation for their use, but also above all of an incentive to develop new environmental technologies. Finally, time-series analyses seem necessary for studying the development of technologies over time. The basic data which is lacking here could be provided by a regular environmental innovation survey of companies in manufacturing industry and the service sector.

Appendix 1: Results of model estimations

Innovationsziel	*Environmental friendly products*	*Environmental impact production*	*Material consumption*	*Energy consumption*	*Improving Working conditions*
Unabhängige Variable	*Coeff. (t-statistic)*	*Coeff. (t-statistic)*	*Coeff. (t- statistic)*	*Coeff. (t- statistic)*	*Coeff. (t- statistic)*
Market structure					
company size in employees (log)	- 0,281 (-3,213)	-0,349 (-3,893)	0,092 (1,130)	-0,017 (-2,073)	- 0,391 (-4,521)
company size in employees ($\log^2$)	0,027 (3,564)	0,034 (4,446)	-0,001 (-0,190)	0,018 (2,486)	0,031 (4,192)
Technological Opportunities					
R&D-cooperation				-0,171 (-2,489)	-0,176 (-2,540)
R&D-intensity	-1,477 (-3,034)	-1,736 (-3,524)	-1,302 (-2,762)	-2,789 (-5,617)	-1,744 (-3,478)
Schutzmechanismen					
First mover	0,164 (5,035)			0,064 (2,416)	
Complexity of process		0,057 (2,204)			
Long-term employee relation			0,088 (3,068)		
Copyright	0,066 (2,518)				
other		0,091 (3,351)	0,074 (2,795)		0,074 (2,754)
Informationsquellen					
Company internal	0,125 (3,324)	0,137 (3,739)		0,216	0,116 (3,130)
Suppliers: primary products, materials, components	0,166 (5,617)		0,140 (4,926)	- 0,079	
Universities, technical colleges	0,126 (4,684)	0,098 (3,731)		0,073	0,053 (1,782)
Immediate competitors			0,107 (3,857)		
Customers					0,105 (2,955)
Consultants, market researchers	0,066 (2,172)				0,103 (3,217)
Industry-financed research institutes				0,073	0,084 (2,477)
Supplier of equipment		0,140 (4,979)		0,229	0,147 (5,169)
Staatliche Einflüsse, Kosten und Risiken					
Innovation risk too high	- 0,071 (-2,496)				
Administrative procedures too long	0,106 (4,897)	0,095 (4,379)		0,078	0,085 (3,893)
Lack of capital		- 0,051(-2,196)			
Region					
"New" Laender			0,235 (3,170)	0,559	0,133 (1,740)
Environmenatl policy					
Standards	- 0,108 (-1,744)	0,028	0,905 (1,555)	0,177	0,075 (1,212)
Taxes	0,309 (4,438)	0,118	-0,101 (-1,489)	- 0,124	- 0,089 (-1,280)
Statistics					
Sample size	1195	1161	1206	1171	1148
Likelihood-ratio-test	292,56 (13)	230,33 (12)	104,11 (10)	252,93 (14)	207,53 (15)
Log Likelihood	- 1703,56	-1726,53	-1702,17	- 1714,19	- 1574,21
Pseudo R^2	0,079	0,063	0,03	0,069	0,062

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Figure 1: Impact on German industries caused by environmental policy [median]